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The bulge globular cluster NGC 6553: Observations with HST's WFPC2, STIS and NICMOS

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Abstract. As part of a large HST project to study the formation and evolution of rich star clusters in the Large Magellanic Cloud, we present results for the Galactic bulge metal-rich globular cluster NGC6553. HST observations using WFPC2, NICMOS and STIS were obtained for this cluster. The primary reason for studying NGC6553 is to transform our NICMOS and STIS magnitudes directly into absolute magnitudes. This is particularly important for determining the low mass end of the IMF. NGC 6553 was chosen because its metallicity, [Fe/H] ≈ -0.2, is representative of the metallicities of the young and intermediate age LMC clusters.

1. Introduction

The Galactic bulge globular cluster NGC 6553 was observed as part of a large HST project to study the formation and evolution of rich star clusters in the Large Magellanic Cloud. A total of 95 orbits were awarded to this project in Cycle 7, using WFPC2, STIS (in imaging mode), and NICMOS to obtain multi-wavelength photometry in eight clusters with ages $\sim 10^7, 10^8, 10^9$ and 10^{10} years. Data acquisition was completed in November 1998. Early results have been presented by Beaulieu et al. (1998), Elson et al. (1998c), and Johnson et al. (1998,1999). The results of a pilot study of one of the clusters in the sample are described in Elson et al. (1998a,b).

NGC 6553 was observed for calibration purposes, in order to transform NICMOS and STIS magnitudes directly into absolute magnitudes on a standard system. Beyond calibration, our data allow us to investigate various properties of the cluster. Clusters like NGC 6553 are of particular interest in that they serve as tracers of the formation and evolution of the bulge component of the Milky Way. In this regard, any spreads in age or metallicity among bulge clusters provide clues concerning the enrichment history of the bulge, the timescale for its formation, and the time of its formation relative to the halo and disk. Their

dynamically vulnerable location also allows the effect of tidal shocking on the structure and stellar content of the clusters to be explored. Our WFPC2 data allow us to probe the stellar content of NGC 6553 well below its main-sequence turnoff, and determine accurate values of the cluster's distance and reddening. Our STIS data allow us to determine a deep luminosity function (LF) which may be compared with LFs in other Galactic globular clusters.

We are investigating differential reddening as the explanation for all the apparent peculiarities of this cluster. The peculiarities include the red giant branch (RGB) bump, the tilted horizontal branch (HB), the apparent "second turnoff" and the unusual LF consistent with these studies.

2. WFPC2 CMDs

The main features of the colour-magnitude diagrams (CMDs) include the blue population brightwards of the main-sequence turnoff, the tilted HB and the clump below the HB. A 12 Gyr isochrone for [Fe/H]$= -0.4$, reddening E(B $-$ V) $= 0.7$, and distance modulus $(m - M)_0 = 13.7$ fit best the data (Fig 1). Also visible in the CMDs of WFPC2 is an apparent "second turnoff", an excess of stars near $(V, V - I) = (21, 2)$. The second fainter turnoff is particularly prominent in chips WF4 and fainter in the PC and WF2 (where WF3 is the cluster core). It is not understood yet what this turnoff represents, it could be associated with the Galactic bulge, or could be the result of patchy reddening (see next subsection).

2.1. A tilted horizontal branch

It has been noted by previous authors that the HB in NGC 6553 is far from horizontal. Its range in V spans ~ 0.5 mag. Some authors have attributed this tilt to differential reddening across the face of the cluster (cf. Guarnieri et al. 1998). Others suggest that metal line blanketing can produce a tilting of the HB (cf. Ortolani et al. 1990).

2.2. RGB bump

The HB shows up prominently, peaking at $V_{555} = 16.6$ (Fig 1). A second peak is clearly visible ~ 0.9 magnitudes below the HB. This has been discussed, for example, by Sagar et al. (1999) and attributed to a phase of stellar evolution where the star becomes fainter. Other authors have suggested that it could also be due to the superposition on the cluster RGB of background HB stars, however this is not consistent with the redward shift of the background RGB.

3. STIS-LP LF

Fig 2 shows the STIS-LP LF for NGC 6553, both raw and corrected for incompleteness. In the bottom panel, the instrumental magnitude has been transformed to an absolute magnitude in the STIS-LP passband, adopting an aperture correction of -0.5 mag, a zero point of 23.4 mag, a reddening of $E(B - V) = 0.7$ and an absolute distance modulus of $(m - M)_0 = 13.7$. The reddening and distance information are from Guarnieri et al. (1998). The value of E(B $-$ V)

has been transformed to an absorption in the STIS-LP passband by $A_{R(STIS)} = 2.505 \cdot E(B-V)$. This LF differs from that of most globular clusters (cf. Elson et al. 1998c), possibly because of significant uncorrected extinction.

4. NICMOS2 CMD

Fig 3 shows the CMD of V_{555} vs $(V_{555} - H_{160})$ for the short exposure. A 12 Gyr isochrone for [Fe/H]$= -0.4$, reddening $E(B-V) = 0.7$ and distance modulus $(m-M)_0 = 13.7$ is overlayed but clearly does not represent the data. The considerable width of the main sequence, though less than in Fig 1, suggests important patchy extinction which may also be responsable for the difficulty in fitting isochrones.

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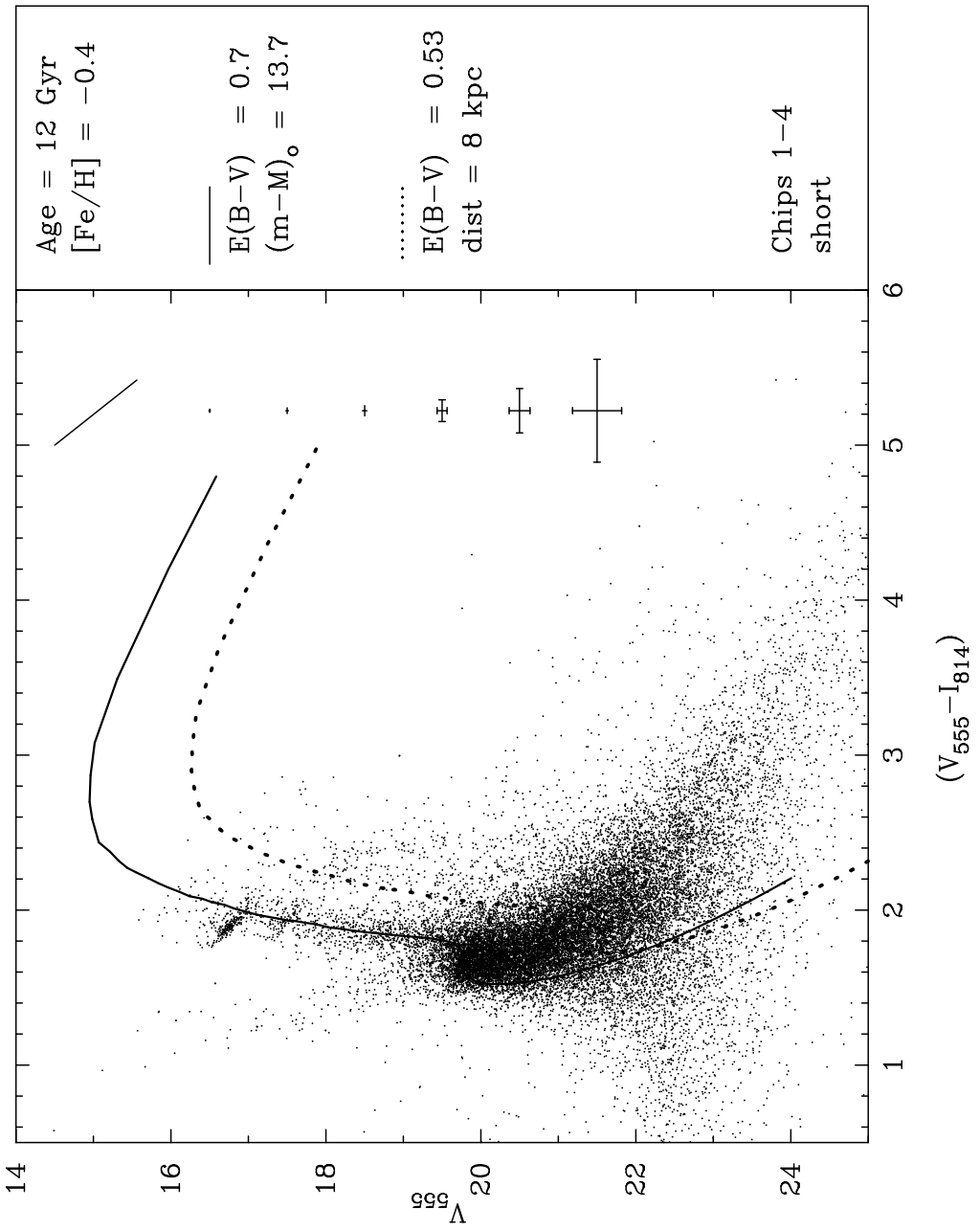

Figure 1. CMD for the short exposure observations of NGC 6553. A 12 Gyr isochrone (Bertelli et al., 1994; Wortley, 1998) for [Fe/H]= −0.4, reddening E(B − V) = 0.7, and distance modulus $(m - M)_0 = 13.7$ is superposed. The dashed isochrone represents the background bulge stars and has [Fe/H]= −0.4, E(B − V) = 0.53, and distance 8 kpc.. The diagonal line indicates the reddening vector. The saturation limit is at $V_{555} \approx 15.5$. The very considerable width of the main sequence and the tilted HB suggest this CMD is strongly affected by patchy extinction.

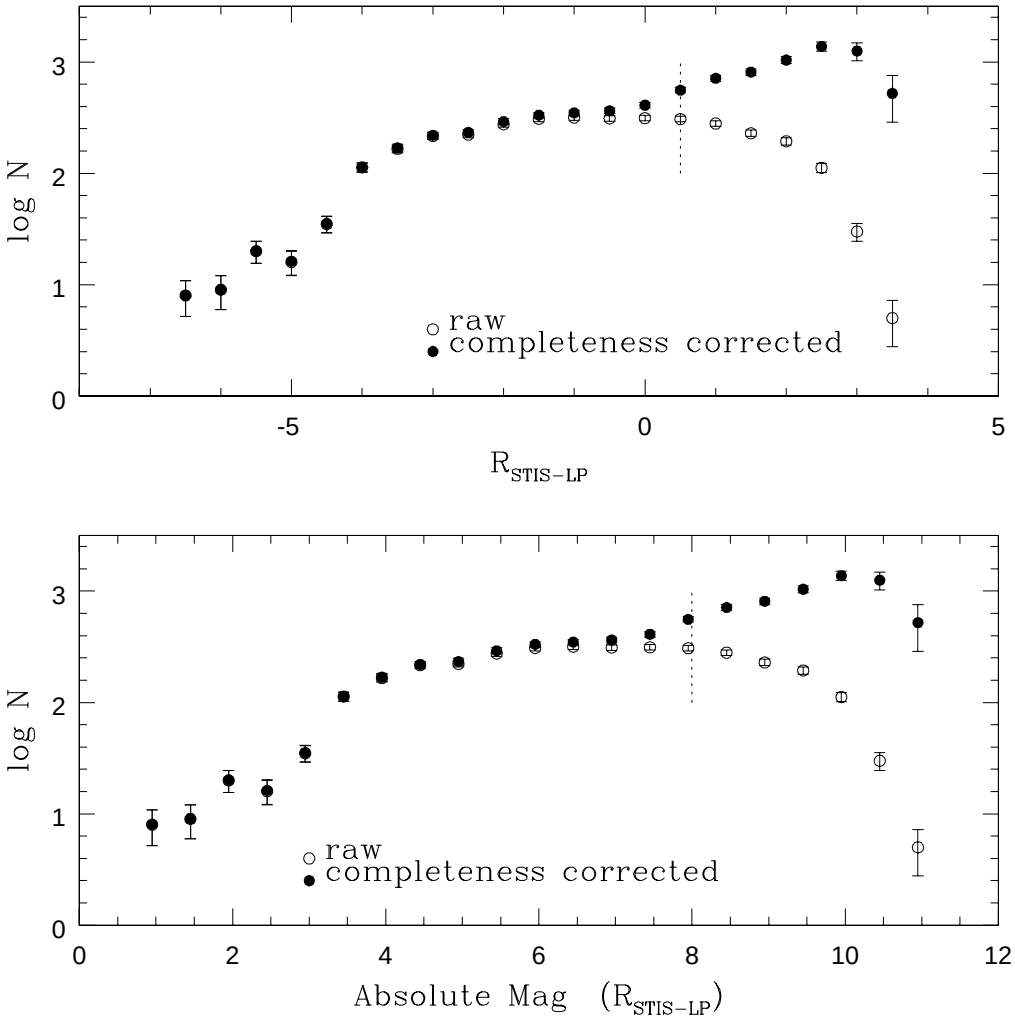

Figure 2. Instrumental and absolute luminosity functions derived from STIS for a field $\sim$ 1 arcmin from the centre of NGC 6553. In the bottom panel, absolute magnitude = $R_{STIS} - 0.5 + 23.4 - 13.7 - 1.75$. Poisson error bars are shown. Open circles are from raw counts and filled circles have been corrected for incompleteness. The vertical dashed line indicates the 50% completenss limit. The LF may still be substantially affected by differential extinction.

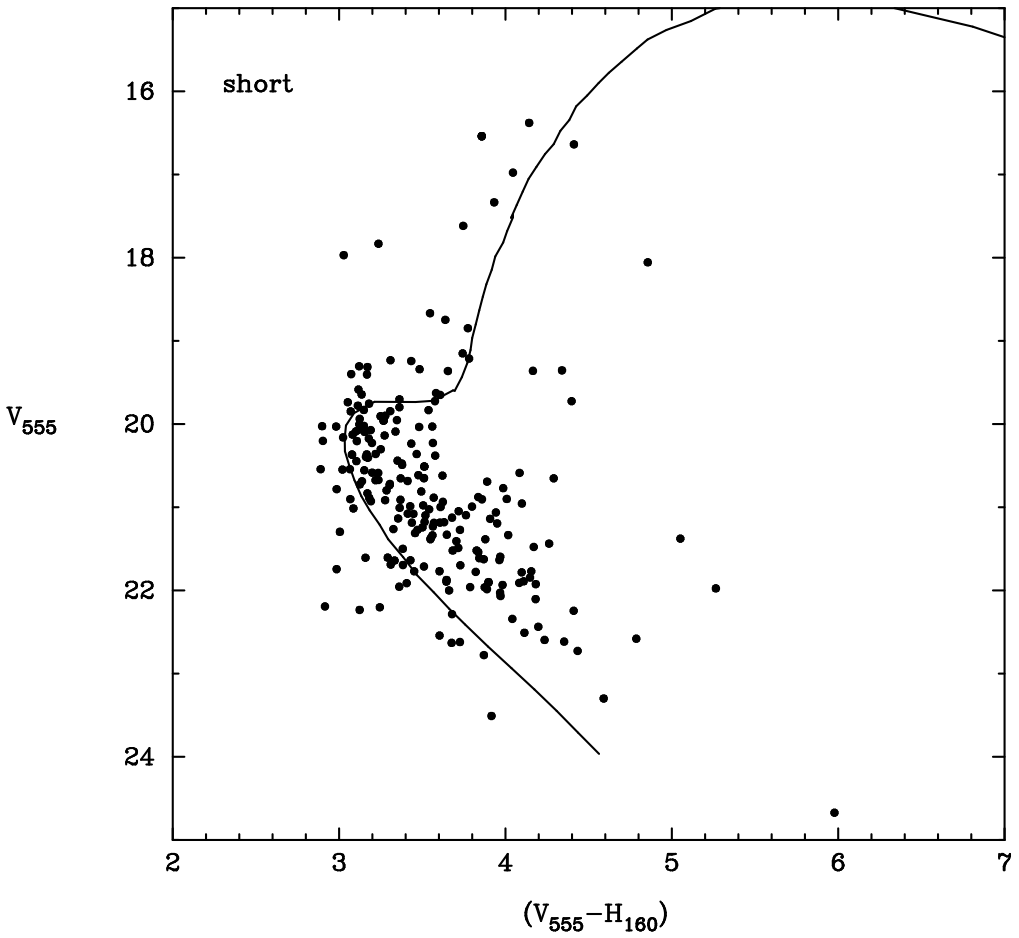

Figure 3. CMD of V_{555} vs $(V_{555}-H_{160})$ for the short exposure observations of NGC 6553. A 12 Gyr isochrone for [Fe/H]$= -0.4$, reddening $E(B-V) = 0.7$ and distance modulus $(m-M)_0 = 13.7$ is superposed.